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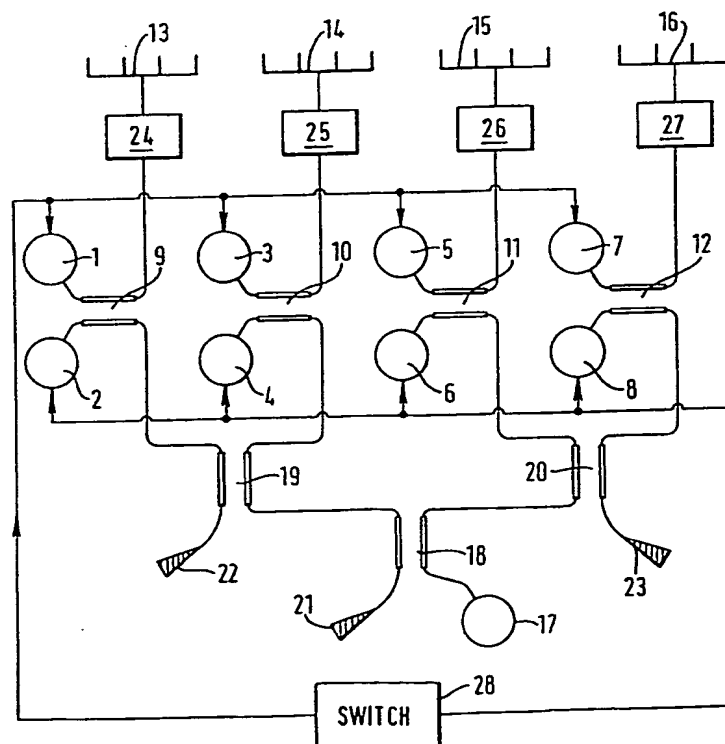
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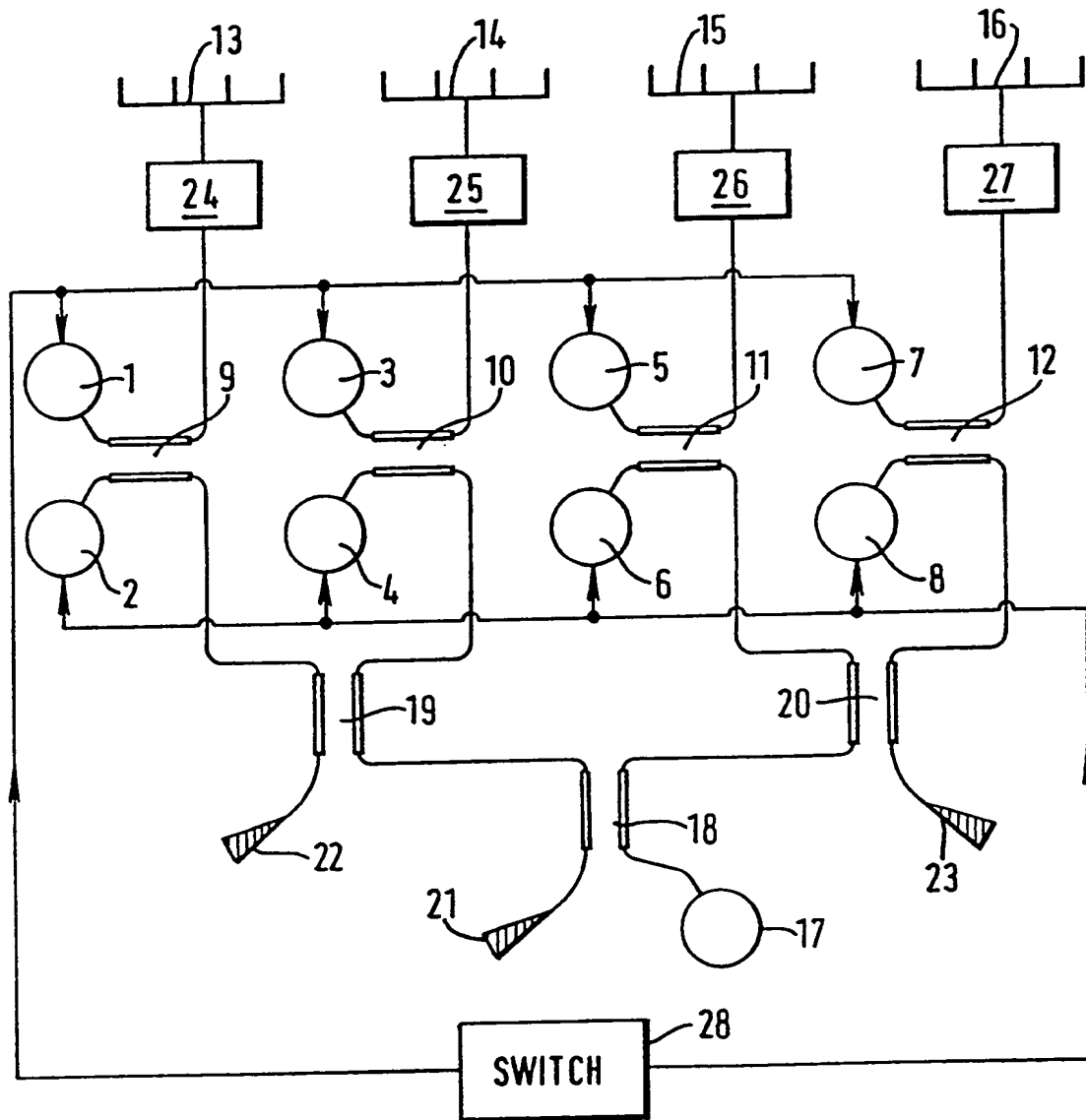
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(54) **Fixed phase relationship multiple magnitron oscillator**

(57) A plurality of magnetrons 1 to 8 which are connected to the inputs of directional couplers 9, 10, 11 and 12, each having two outputs, one of which is connected to a section 13, 14, 15 and 16 of an array of radiating elements. The other outputs are connected via further directional couplers 19, 20 and 18 to a master oscillator 17. The output of the master oscillator 17 causes the magnetron outputs to remain in a substantially fixed-phase relationship. The invention is particularly applicable to high-power level systems.



GB 2 228 841 A



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MAGNETRON ARRANGEMENTS

This invention relates to magnetron arrangements and more particularly, but not exclusively, to arrangements in which a plurality of magnetrons are required to supply a plurality of separate radiating elements with high power radiation.

When it is desired to produce a radiation pattern having a high power density, it often proves necessary to use an array of radiating elements rather than a single antenna to avoid arcing or other forms of electrical breakdown which would otherwise occur. It is then necessary to maintain a fixed phase relationship between the outputs of the magnetrons for successive pulses to enable the desired radiating pattern to be preserved.

One way in which the outputs of the magnetrons may be kept in a fixed phase relationship is to inject each magnetron with the output from a single master oscillator so that each magnetron is locked in phase to the master oscillator. Each magnetron then feeds power to a group of radiating elements that form part of the radiating array. However, where it is required to operate the arrangement at high power levels, for example of the order of 100MW or more at microwave wavelengths from each magnetron, serious practical difficulties ensue.

The use of such an arrangement requires that up to one tenth of the output power of the magnetron is required

from the master oscillator to phase-lock the high power magnetron. It is necessary to include some form of isolator to prevent power from the magnetrons being fed back to the master oscillator. Such isolators typically include ferrite materials which are not capable of handling the high powers contemplated. In an alternative arrangement, the magnetrons may be arranged to have two output coupling arrangements, one of which couples power from the magnetron to the radiative load and the other of which is used to supply the phase-locking signal from the master oscillator to the magnetron. However, the magnetron outputs are of particularly complex construction and the mismatches introduced into the arrangement reduce its efficiency and result in unacceptable power losses.

The present invention arose from an attempt to provide an improved magnetron arrangement which is particularly suitable for high-power use.

According to the invention there is provided a magnetron arrangement comprising a plurality of magnetrons, each magnetron being associated with a respective directional coupler, the output of each magnetron being connected to one of the inputs of its associated directional coupler, and one of the outputs of each directional coupler being connected to a respective one of a plurality of loads and another of the outputs being connected to receive an output signal from a master oscillator such that the master oscillator signal

maintains the output signals of the magnetrons in a substantially fixed phase relationship. By employing the invention, magnetrons with a conventional single output coupling system may be employed and the master oscillator may be isolated from the magnetron outputs without the need to use any non-reciprocal or non-linear elements. A magnetron arrangement in accordance with the invention enables a plurality of output signals to be phase locked and may be operated at particularly high power levels where each magnetron has an output of the order of 100's of megawatts. Such an arrangement may be particularly advantageously employed where the loads are radiative elements and it is necessary to maintain a controlled radiation pattern at high power levels.

It is preferred that each directional coupler is associated with two magnetrons, the outputs of which are connected to respective different inputs of the directional coupler. This permits a phase-locking signal from the master oscillator to be fed equally to a pair of magnetrons. The directional coupler may be such that when each one of its inputs is fed by a signal of the same frequency and amplitude, the relative phase of the two signals on the inputs may be adjusted such that the two input signals add to give twice the input power at one output and the zero power in the other output which is connected to the master oscillator.

Preferably, means are included for simultaneously

switching off corresponding ones of each pair of magnetrons associated with the directional couplers. Then, if one of the magnetrons fails, the other corresponding magnetrons in the remaining pairs may be switched off so that power is delivered to the loads in the same proportion as before but at a lower level.

The invention is particularly advantageously applied where the loads are radiative elements.

Advantageously, the magnetrons are nominally identical and are arranged to operate at substantially the same frequency. It is also preferred that the master oscillator is a magnetron and advantageously, the output signal of the master oscillator is at the same frequency as the outputs of the plurality of magnetrons and the master oscillator is nominally identical to the magnetrons. The magnetrons may be, for example, relatively narrow bandwidth devices having high external-Q (Q_e).

It is preferred that the directional couplers are 3dB couplers which advantageously are slot-type 3dB couplers. This type of directional coupler includes two lengths of waveguide having a common wall which is slotted to provide coupling between them.

One way in which the invention may be performed is now described by way of example with reference to the accompanying drawing in which the sole figure schematically illustrates a magnetron arrangement in

accordance with the invention.

With reference to the Figure, a magnetron arrangement in accordance with the invention is employed to supply an array of radiative elements with high power radiation.

The arrangement includes a plurality of nominally identical magnetrons 1 to 8 which are arranged to operate at the same frequency. The output of each magnetron is connected to one of the inputs of an associated 4-port directional coupler 9, 10, 11 and 12 which is of the 3dB slot type. Each directional coupler 9, 10, 11 and 12 has two outputs, one of which is connected to feed energy to a respective section 13, 14, 15 and 16 of the array of radiative elements. The other output of each of the directional couplers 9, 10, 11 and 12 is arranged to receive the output signal of a master oscillator 17, which in this embodiment of the invention is a magnetron, which operates at the same frequency as the magnetrons 1 to 8 and is nominally identical to them, arranged to supply energy to the array.

The master oscillator output is applied to one port of a four-port directional coupler 18, two other ports of which are connected to further directional couplers 19 and 20 and the fourth port being connected to an absorptive load 21. The further directional couplers 19 and 20 are in turn connected to supply the master oscillator output signal to the directional couplers 9, 10, 11 and 12. Absorptive loads 22 and 23 are connected to one of the

ports of the directional couplers 19 and 20 respectively.

The electrical path lengths from the magnetrons 1 to 8 to the radiative sections 13, 14, 15 and 16 are substantially the same to minimise phase differences incurred by signals transmitted along them. Phase and amplitude control circuits 24, 25, 26 and 27 are also included to control the signals applied to the sections 13, 14, 15 and 16.

A switching circuit 28 is connected to the magnetrons 1 to 8 and enables corresponding ones of each pair of magnetrons to be switched off simultaneously. Thus, by applying appropriate control signals to the circuit 28, either magnetrons 1, 3, 5 and 7 may be switched off or magnetrons 2, 4, 6 and 8.

During operation of the arrangement, the signal from the master oscillator 17 ensures that the phases of the output signals from the magnetrons 1 to 8 are maintained in a substantially constant phase relationship. In this embodiment, the magnetrons are arranged to operate such that there is no phase difference between their output signals but this need not necessarily be the case.

Each input of the directional couplers 9, 10, 11 and 12 is fed by a signal of the same frequency and amplitude. The relative phases of the signals on the inputs of each directional coupler are adjusted such that twice the input power is fed via one of the directional coupler outputs to the radiative sections and zero power is present at its

other output. The zero power output port is that which is connected to receive the output of the master oscillator 17, the phase-locking signal from the master oscillator 17 being fed equally to each pair of magnetrons.

If one of the magnetrons should fail, the switching circuit 28 may be used to switch off other magnetrons which correspond to it in the remaining pairs. The output pattern at the radiating array thus remains the same but its power level is reduced to one quarter that of what it was previously. One quarter of the magnetron output power is also fed along the other outputs of the directional couplers 9, 10, 11 and 12 to be absorbed by the loads 21, 22 and 23.

Although the described embodiment utilises eight magnetrons, it is, of course, possible to employ the invention with fewer or more magnetrons.

CLAIMS

1. A magnetron arrangement comprising a plurality of magnetrons, each magnetron being associated with a respective directional coupler, the output of each magnetron being connected to one of the inputs of its associated directional coupler, and one of the outputs of each directional coupler being connected to a respective one of a plurality of loads and another of the outputs being connected to receive an output signal from a master oscillator such that the master oscillator signal maintains the output signals of the magnetrons in a substantially fixed phase relationship.
2. A magnetron arrangement as claimed in claim 1, wherein each directional coupler is associated with two magnetrons, the outputs of which are connected to respective different inputs of the directional coupler.
3. An arrangement as claimed in claim 2 and including means for simultaneously switching off corresponding ones of each pair of magnetrons associated with the plurality of directional couplers.
4. An arrangement as claimed in claim 1, 2 or 3 wherein the loads are radiative elements.
5. An arrangement as claimed in any preceding claim wherein the magnetrons are nominally identical.
6. An arrangement as claimed in any preceding claim wherein the master oscillator is a magnetron.
7. An arrangement as claimed in claim 6 wherein the

master oscillator is arranged to operate at substantially the same frequency as the plurality of magnetrons.

8. An arrangement as claimed in claim 7 wherein the master oscillator is nominally identical to the magnetrons of the plurality.

9. An arrangement as claimed in any preceding claim wherein each directional coupler is a 3dB coupler.

10. An arrangement as claimed in claim 9 wherein each directional coupler is a slot-type 3dB coupler.

11. An arrangement as claimed in any preceding claim and including means for adjusting the frequency and phase of the output signal from each magnetron.

12. An arrangement as claimed in any preceding claim wherein the master oscillator signal is applied to the outputs of the directional couplers via a network of other directional couplers.

13. A magnetron arrangement substantially as illustrated in and described with reference to the accompanying drawing.